A Consumer's Guide to Statistics in Research

Hold the Variation, Extra Randomization Please!

By Susan D. Day

The word "statistics"

has made many a strong man or woman run for cover. We've all seen politicians and special interest groups use "statistics" to present facts to support their viewpoints. Statistics are a tool—a tool that can be used to extract useful information from all kinds of data. But understanding and interpreting data is not always a straightforward process, especially when the organism being studied is as complicated as a tree and its environment.

I'd like to present a few examples to illustrate some basic issues that color our interpretation of research: *randomization*, *replication*, and *inference space*. These are things I try to keep in mind when I'm reading any research results, whether it's traffic safety statistics or tree research. I hope you'll find some tidbits here that will help you assess research with a critical yet understanding eye. I'll address other topics relating to statistics in future articles.

How many trees did you say you treated?

Replication, a scientist's favorite word. An entire study can be replicated. For example, Dr. Treelove in the East installs a research project to evaluate Magic Tree Ointment (MTO). At the same time, his colleague Dr. Arbocare installs the same project in the West. These studies might tell us that Magic Tree Ointment does not improve growth of sweetgums (*Liquidambar styraciflua*) in the West any more than it does in the East. That is to say, in addition to the studies reinforcing each other, the inference space (keep reading if you want to know more about that!) of the research is expanded. More commonly, however, we are talking about replications within an experiment. Hand-in-hand with randomization, replication allows us to use statistics—that wonderful tool that can tell us whether any differences are most likely due to treatment.

Every research project starts with a question. Let's say that we want to see whether Magic Tree Ointment makes trees grow faster. We smear Magic Tree Ointment on the leaves of one tree, and the tree grows dramatically the next year. Even the most uncritical observer can find fault with that approach. What are we comparing it to? Maybe it rained a lot that year. Clearly a "control" treatment is needed.

The next time, we smear Magic Tree Ointment on a recently planted jacaranda tree (*Jacaranda mimosifolia*), and we use another tree of the same size that is untreated—as our control. The MTO-treated tree grows twice as fast as the control. That's an improvement. But how do we know that our control tree didn't just happen to be genetically slower growing? Or perhaps the drainage was poor, or the tree had been planted deeply in the nursery, or the soil nitrogen content was low, or it had been attacked by insects, or a vole gnawed at the bark, or . . . The list goes on.

This is where randomization and replication come in to save the day. This time, we have a group of ten young jacaranda trees in a field. We randomly select half the trees to be smeared with Magic Tree Ointment. That means we have five replications of each treatment—the smeared and the nonsmeared, as it were. Four out of five of the MTO-smeared trees grew faster than four out of five of the controls. How likely is that just to have been by chance?

Aha! That is the question that statistics can help us answer. Statistics can calculate the likelihood that the differences we are seeing are due to the Magic Tree Ointment rather than other factors, such as natural vigor of the individual tree, prior handling, site conditions, and a thousand more. Without replication, statistical tools cannot even be applied to this question. If we don't know how much variation there is among untreated trees, how can we possibly determine whether the growth of the MTO-treated trees is within that range of variation or not? Replication is the absolute key, and randomization helps keep the playing field level.

The researcher tries to keep variation among the trees to a minimum. Otherwise, it might mask the effects of the Magic Tree Ointment. If we had chosen all different sizes and species of trees, the growth rates would have been all over the place (or "highly variable," as some might say). It would have been very hard to determine whether Magic Tree Ointment does any good at all. So, we used only jacaranda trees of the same age and on the same site to reduce this variation. Even so, the critical reader is already wondering, "What about sugar maples? Or live oaks?"

Wait a minute! How old were those trees?

This brings me to a perennial difficulty with tree research—*inference space*. Researchers typically state their conclusions with many qualifications: "For healthy, young trees of species X growing in these site conditions, there is little evidence that treatment Y affected growth over the time period studied." There's a lot of wiggle room there, but the idea is clear. Nobody is making any claims about species A through W or for longer time periods or different sites. This is the author's nod to *inference space*—or just how far we can extrapolate study results to the real world.

If we conduct a study on one-year-old seedlings, is it reasonable to assume a 200-year-old tree would react the same way? What about a 30-year-old tree? What if the study is about root severance? What if it concerns species tolerance to high soil pH? Inference space in our MTO study is tied to statistics but is really a judgment based on our broad understanding of tree biology.

Inference space is one of the most frustrating aspects of research for those on the receiving end of the information. On one hand, there is a temptation to say, "Come on, let's cut to the chase. Does thinning reduce storm damage or not? Let's have a clear answer!" On the other hand, when one is in a critical mood, one might say, "Sure, thinning affects Bradford pears, but their canopies are so dense and the branching so poor. What does that tell me? This study doesn't prove anything!"

These are opposite sides of the same coin. Most questions can't be answered conclusively by any study—no matter how large or brilliantly designed. Each research result goes into the pool of our collective knowledge. Some results call previously held beliefs into question; others reinforce evidence presented in earlier studies. We view each study in the context of that larger pool of knowledge.

From our Magic Tree Ointment research, the practitioner will have good, solid information about the efficacy of MTO on young jacarandas in particular growing conditions. But she has to work with a lot of tree species on many different sites! What to do? This is where her expertise as an arborist comes into play. She can take these research results with a grain of salt, but she can also use her understanding of how MTO works along with her knowledge about tree biology, species differences, and other factors to make decisions in the field until more information is available. A dose of skepticism is always good to have around.
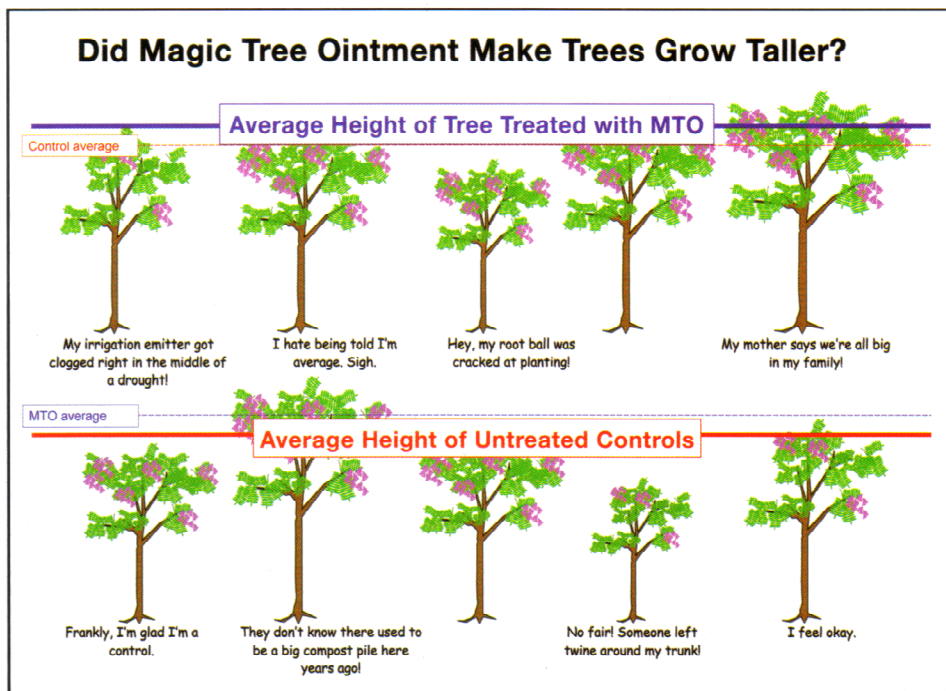
When an article is published about what causes cancer or makes children smarter or how we are all going to vote come Election Day, it is up to you to make a final interpretation of the facts. With arboriculture research, each study should be considered as adding to our body of knowledge. Rarely, if ever, does a study definitively answer a research question completely, for all time. By carefully designing studies to hone in on the right variables, arboriculture research will march on, bringing us more knowledge, more technology, and better ways to care for trees.

What's next?

In future articles, we'll discuss *causation versus association* and *how many replications do you need, anyway?* (That'll be fun! Remember, research shows that just *thinking* about statistics makes you feel smarter, and that's good for your health! At least I think I read a study that said that. . . . I feel better already.)

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Magic Tree Ointment and the research here described are works of fiction. No relation to real studies, products, persons, or events is implied or intended.

Did Magic Tree Ointment Make Trees Grow Taller?

Average Height of Tree Treated with MTO

Control average

My irrigation emitter got clogged right in the middle of a drought!

I hate being told I'm average. Sigh.

Hey, my root ball was cracked at planting!

My mother says we're all big in my family!

MTO average

Average Height of Untreated Controls

Frankly, I'm glad I'm a control.

They don't know there used to be a big compost pile here years ago!

No fair! Someone left twine around my trunk!

I feel okay.

Did Magic Tree Ointment make these trees grow taller? On average, MTO-treated trees did grow taller. The question is, is it because of the Magic Tree Ointment or by chance? Statistics can help us understand the probability by mathematically analyzing the variation in height over the whole experiment, within groups of trees receiving the same treatment, and between groups of trees receiving different treatments. Many things besides the treatment being studied can cause variation in tree heights—just see what the trees have to say!